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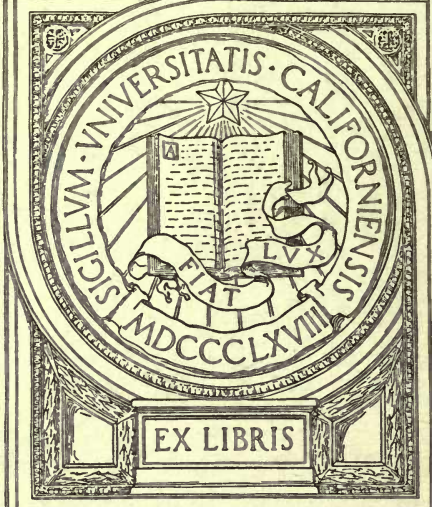
IN MEMORIAM
George Davidson
1825-1911



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METRIC SYSTEM.

BY

COLEMAN SELLERS,

OF WM. SELLERS & CO.

taking it for granted that if it would be introduced we would all be gainers. I felt that way myself at one time but when I was as familiar with the system as with our own through long use I soon changed my mind and now I hold that could we secure its introduction without cost to any one it would be a mistake to put it into use as I am well convinced that it is not well adapted to the wants of the people. Thanking you for you letter I am

Yours truly,

Coleman Sellers

Rec'd Mar 18/81

Philadelphia March 11 1881

Mr. George Davidson,

San Francisco Cal.

Dear Sir:

Your fav'r of the third inst is at hand and it gives me pleasure to mail you at once one of the pamphlets asked for. The number of letters I recieve in reference to the paper show how much need there is for those who have tried the metric system to give their views in regard to its inforced adoption. Some little time ago many who were loth to take the trouble to learn the system were still unwilling to say anything against its introduction taking it for granted that if it would be introduced we would all

THE METRIC SYSTEM;

IS IT WISE TO INTRODUCE IT INTO OUR MACHINE SHOPS?

A PAPER READ BEFORE THE

AMERICAN SOCIETY OF MECHANICAL ENGINEERS,

At their Meeting, November 4, 1880, held at New York.

BY COLEMAN SELLERS.

(OF WM. SELLERS & CO.)

Vice President American Society Mechanical Engineers; member of American Society of Civil Engineers, of the Franklin Institute of the State of Pennsylvania, of the American Philosophical Society, and of the Academy of Natural Sciences of Philadelphia; Corresponding member Society of Arts ~~and Sciences~~, Geneva; member of the Royal Norwegian Order of Olaf, etc., etc.

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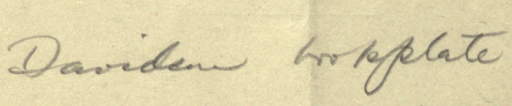
1880.



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THE METRIC SYSTEM;

IS IT WISE TO INTRODUCE IT INTO OUR MACHINE SHOPS?

By Coleman Sellers, M.E.

Read before the American Society of Mechanical Engineers, Nov. 4, 1880.

The organization of a Society of Mechanical Engineers offers a convenient and fitting opportunity for the presentation of the views of a mechanical engineer on the subject of the metric system to members of his own profession and to those who are similarly interested. During the month of May, 1874, I had the honor of reading before the American Railway Master Mechanics' Association a paper on "The Metric System in our Workshop; will its value in practice be an equivalent for the cost of its introduction?" In that paper I treated the subject mainly in reference to its cost. From what has since been published by those who advocate the enforced substitution of the metric system for the weights and measures in common use in this country, it is evident that the subject will bear to advantage a different treatment. I now propose to supplement the question of cost by an endeavor to show that the system, *per se*, is not so well adapted to the wants of machinists as is the one now in use, and that its enforced introduction will do harm to our industries in place of doing good.

In addressing to the members of the American Society of Mechani-

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cal Engineers arguments in opposition to any compulsory legislation in this direction, I feel that I am speaking to men who are familiar with the subject and who have already given thought to the results likely to obtain from the proposed change in the system. I feel, too, that I am speaking to those whose habit of thought fits them to consider the subject without bias; mechanical engineers, of all men using weights and measures, are the ones most eager to adopt what in the end will be of the most use. To them weights and measures are not abstract ideas, but tangible substances. Engineers make the machines for weighing and measuring, and the result of their use of those machines exists as fixed matter, costing millions upon millions of dollars.

To the great bulk of mankind engaged in trade, in buying and selling, in bartering and exchanging, it matters little what system they adopt; it matters little whether they are obliged to use a yard-stick or a metre-rod, pounds or kilogrammes, quarts or litres. The cost to them of a change from one to the other is the cost of the few devices needed in weighing and measuring; the *rationale* of the system may never enter their thoughts.

With the machinist the case is different. He must not only possess costly means of measuring and weighing, with a degree of exactness unknown to others, but the results of these weights and measurements are fixed and unalterable. Enormous expenditures on tools, on drawings, on patterns, on everything he uses in making or building his machines are on what is involved in the primary system used in determining weight and size. The product of this expenditure means everything that makes modern civilization possible. I propose, in this paper, to consider the subject only as it relates to our own profession; not in regard to its effect on the grocer, the dry goods man, or on the druggist. I propose to show why, after nearly twenty years' constant use of the metric system of measurement, I record my opposition to any enforcing legislation in this direction, because *the metric system is not well adapted to the practice of the machine shop.*

To render my arguments of any value I must endeavor to express myself so as to be understood by those who are not mechanics, and must crave the indulgence of my associates for dwelling, as I shall have to, on details so familiar to them and for making my explanation of the usages of the workshop so elementary.

For nearly twenty years one large department of Wm. Sellers &

Co.'s establishment has been worked on the metric system, as thoroughly as the system can be worked in any machine shop; as thoroughly as it is worked in France or Germany. The drawings made for this department are to the metric scale, figured in millimetres. The small tools and gauges are to metric measurement only, and the product of the shop is scaled to metric sizes and called by names based on those sizes.

During all these years, and for many years before, we have taken pains to inform ourselves, so far as lay in our power, as to all possible good to be derived from the system, in the drawing room as well as in the shop. We inquired into its defects and endeavored to overcome them by the same means as are resorted to in metric using countries. The system is urged by theorists as a perfect system. All nations, we are told, should adopt it to bring about a desirable unity in weights and measures, even if all cannot be made to speak our language and all cannot be equally good and pious, as measured by some international scale of goodness and piety.

The metric system was legalized here in May, 1866. Some of its enthusiastic advocates now urge its being made exclusive and obligatory. Societies are organized to teach its principles to the people, and much money has been expended in publishing, but up to this time few conveniences have been placed in the hands of mechanics to enable them to use it in their calculations. Some years ago (the conditions remain the same to-day) letters addressed to leading publishing houses asking for metric books in the English language, equivalent to those to which we constantly refer, which books are as necessary to us as are our other tools, failed to bring a single favorable answer. What was asked for, was some book in which formulæ shall be given in the most convenient form expressable in relation to the metric nomenclature. Many books can be found urging its merits as a system, and the writers of these, in showing (?) that the metric system can be learned entire in say fifteen minutes, may think they have done what is needed, but no book yet published in the English language, so far as I have been able to learn, even approximates to what is required. We have nothing like the hand-books published in German. These Germans, in teaching their people, gave side by side in these almanacs of mechanics the formulæ expressed in Prussian inches and in metres. When the year 1880 came around they dropped the Prussian inch from these books when it was possible so to do. There are many

very good books of tables for the ready conversion of the measurements of one system into the other, but unless an engineer is as familiar with the metric system as with his own they aid him but little. On the other hand, our English work books are many and valuable. The great bulk of literature of primary importance to mechanical engineers is in English and expressed in feet and in inches.

The absence of these help books need not, however, prevent any one *familiar with the metric system* from using it in his practice. If he can think in the new system he can work in it too. He can formulate what is directly needful to him if he will take the time and trouble so to do. The absence of these books has not prevented us from using it or familiarizing ourselves with it, and had it proved worth the effort, and possible, we would long ago have placed ourselves in position to advocate it, as none can knowingly do who have not tried it. In designing any engineering work, proportioned structures can be produced by either scale; the working drawings can be then made to whatever system obtains in the shop of erection. This change from one or the other system in the drawing room is a matter of no difficulty whatever. The change from one system to the other in the workshop, however, involves more than the usual advocates conceive of.

To show the measure of the misapprehensions as regards its effect on our profession, on the part of the enthusiastic advocates of the exclusive metric system, I will pass by some lesser lights and seek illumination from the central luminary.

Mr. Frederick A. P. Barnard, S.T.D., LL.D., who, besides being President of Columbia College, in New York City, is also President of the American Metric Bureau, and of the American Metrological Society, etc., etc., said, Dec. 27, 1877: "It is now little more than a dozen years since the movement in favor of the reform of the confused metrological system of the United States was set on foot. Originating with a few *advanced thinkers*" (the italics are mine) "and regarded with indifference by the multitude, it encountered, as it is the fate of all efforts to emancipate mankind from the burden of traditional evils, to encounter a much larger degree of opposition than of encouragement or favor." Then, after denouncing many of those who oppose the forced introduction of the system (see page 279 and elsewhere in his Metric System) says on page 283 of the same book, "Among the arguments urged by those who maintain the impossi-

bility of change only one appears to have much force, and that is the argument drawn from the dependency of machinery upon minute exactness in the measurements of parts and from the great expense which would attend the adaptation of machine shops and machines to a new system." Quoting the majority report of the Franklin Institute as to probable cost, and referring to the second report of the committee of the New York University Convocation, in which report the number of dimensions requiring separate indications on the drawings of a twenty-five-horse-power steam engine are given, he continues: "Singularly enough these statements, and all the rest of the same class in both the reports referred to, instead of being arguments against the abolition of the present metrological system and the substitution of the metric for it, afford the strongest reason for believing that that is precisely the thing which ought to be done. We desire, I suppose, to create a demand for our steam engines and our manufacturing machinery on the continent of Europe." * * * * "But a steam engine or a machine, all of whose parts are measured in English linear measures, if transferred to a metric country and there, by accident, disabled, becomes nearly useless, *since the shops of such a country afford no facilities for repairing it*," etc. (the italics again my own).

It seems needless to tell engineers that these statements show so entire an ignorance on the part of Mr. Barnard of the merits of the case as can scarce be credited from such a source. I feel ashamed to tender to him an explanation of what is involved.

The unit of measurement used in making a machine does not in any way complicate the repairs of that machine. Machines built in England do not always agree with any of our even sizes, yet this discrepancy is a matter of no moment in the repairs of any of them. If we fail to find sizes corresponding to our sizes in English machines, presumably built on the same scale of linear measurement as are our own, neither do we find even millimetre sizes, always, in machines from France or Germany.

Wm. Sellers & Co. make injectors for feeding boilers. They make them to the metric scale. They were doing so some years before Mr. Barnard's "few advanced thinkers" went into the metrological reform business. Their instruments are made from drawings figured in millimetres in all parts, except where screws and screw threads are needed. Screws to be cut on existing lathes cannot be conveniently figured

metrically, unless we adopt the custom of some German shops to figure in one dimension and make gauges to some other one. A screw bolt in Germany called 25 mm. diameter must be made 25·4 mm. size to conform to the screw system in use there; it will have 8 threads per inch and consequently 8 threads per diameter (I will explain this later). Screws cannot be metrically divided until metrically divided lead screws have been originated and put in the place of the inch divided lead screws *common to all lathes in all parts of the world.*

The people into whose hands these injectors pass know nothing of the scale of proportions to which they have been made. If some piece needs repairs and its shape has been lost by wear, it is needless to say that a knowledge of the scale would give no clue to that shape, but from some existing original any part can be copied; to copy requires no knowledge of the scale used. Repairs, too, as a rule, require deviation from original size to compensate for wear.

While the value of the unit of measurement may be of little moment in repairs, it is, however, all important in the first production of machines. This leads me to another misunderstanding on the part of those whom Mr. Barnard classes, I presume, with his advanced thinkers; this cleared away will bring us to the positian required in a judicious consideration of the two systems in their application to the machine industries of our country. I quote now from a pamphlet by Mr. Persifor Frazer; this pamphlet, says one of the Metric-Bureau tracts "contains more points, all well made, than any other of the same size on the subject." One of "the points" was suggested to him by the reading of a manuscript paper on the subject, said to have been written by an American engineer. The point made is this: "Lengths, breadths, thicknesses, capacities, and weights of things are related to the accomplishment of man's purposes and are varied to conformity with the inflexible laws of mechanics for different motors, strains, and materials; no change of system will alter in the least their dimensions, though it may give them different names." * * * "The grand truth of mechanics is, that the properties or dimensions of parts of machinery to accomplish any given purpose will be unaffected by any standard of length or weight applied to the part." This is a very good point, sounds well, but as the facts are not *exactly* as stated the point, is a dull one. No workshop in the land is or can be equipped with minor tools and gauges for the production of all sizes by *infinite* gradations. The calculated proportions of machines, the sizes indi-

cated by "the inflexible laws of mechanics," are sizes which must be made to conform to the nearest existing means of production and the merchantable sizes of the matter to be worked into shape.

In shop practice and in mercantile practice, to avoid an endless variety and confusion of sizes, certain dimensions in progressive order are adopted, being the sizes found most useful and most *salable* in practice. These progressive sizes we may call, in order to make the matter easily understood by "advanced thinkers" *Shop sizes* and *Merchant sizes*.

It is by the use of well considered ranges of shop and merchant sizes that the maximum of convenience is obtained at the minimum of cost. Hence one metrological system may be found to possess advantages over another when put to the test of practice. The one that is best in affording the most convenient and the most easily used and *memorized* series of sizes should not be called unphilosophical.

The resting place for memory in the American series of shop sizes is the inch. The inch is subdivided by a process of repeated halving down to $\frac{1}{16}$ in the usual grade of shop and merchant sizes, as in bar iron. This gives 16 sizes to the inch for small sizes; 8, 4, 2 or 1 to the larger sizes.

If a machinist should order from us a set of caliper gauges from $\frac{1}{8}$ up to 2, advancing by $\frac{1}{16}$, and from 2 up to 4 advancing by $\frac{1}{8}$, we are at once informed of the shop system contemplated in his work-shop.

Calculations based on the "inflexible law of mechanics," as read by *finite man*, intimates for the size of a certain part of some machine a dimension 3·95 inches diameter, the prudent engineer has possibly assumed a sufficiently ample *factor of safety* to permit him to select $3\frac{5}{16}$ inches, the nearest shop size below the theoretical size, $3\frac{5}{16} = 3{\cdot}9375$ inches. He desires to use this shop size, because 4 inch iron, an obtainable merchant size of bar iron, will clean up from the black to this size; but if his dimension relates to castings or forgings he may select 4 inches as a shade stronger.

Metric using people have ranges of shop and merchant sizes too; when I come to compare their possible series and their actual series with our own some faint glimmer may come to those who now know nothing about the matter of the fact that our unphilosophic system is not so very bad after all.

In regard to what is involved in each shop size, in a money point of

view, I will give but one single example. The inquiry to our own tool-room keepers for a list of the separate devices used in producing one size, viz. $1\frac{1}{4}$ inch, brings to me the names of 129 articles or sets of articles, such as drills, reamers, gauges, boring bars and cutters, taps of all kinds for all sorts of uses, hardened mandrels, etc. etc. These many pieces, costing many hundred dollars, represent one size only. They tally with and belong to the dimension marked $1\frac{1}{4}$ in many thousand places on drawings, which have been accumulating for years, to patterns loading down our pattern lofts, to gear wheels interchangable over a continent, and to the out-put of our factory for years. So important in an economical point of view has come to be these shop size series, that machines built in one shop, if to be reproduced (not repaired) in another, must be redrawn to conformity to the shop system in use before the work can be begun to advantage. Year by year this harmony in shop sizes in America spreads over a larger area. Entire harmony in essential points exists in many of the leading shops. There are, however, examples still to be found in which machines built in one shop have no dimension in common with the shop sizes we use, as compared to our inch series or our millimetre series, *for we use both.* The expert recognizes such machines as having been built to gauges varied by the judgment of the master workman, or by the more *costly* method of fitting one piece to another already completed, a process not admissible in any well regulated machine shop.

A good workman may by hand construct, we will instance, a sewing machine. He will alter and try, and rearrange its parts until he has satisfied himself with the result. He may not have scaled this machine to any system. It goes to the manufacturer who must per force change some of the wild-cat sizes to conform to merchant sizes of the material to be used. For the rest he may be content to fit gauges and templates to the model and reproduce it in minute exactness. We recognize, however, in every well arranged series of shop sizes, and in the means employed to *maintain size*, the highest value of possible *merchantable* good workmanship, for in such possibilities we recognize economy in tools as well as in work, in interest on capital and in wages. This system has been growing year by year in spite of our so-called unphilosophic metrology. Eli Whitney, in 1798, gave a lesson in this direction when he began to make muskets with interchangeable parts in Springfield, Massachusetts, but it was not until 1855 that the English Government recognized what Whitney had

done by importing American gun-making machinery. Since Whitney's time, the standard system has been carried into all branches, not only of our own trade, but into all the requirements of other trades as well.

The metrology of the American shops is based on the inch, and on it only. This dimension is cut up into minor parts by halving to any degree of subdivision, practically in shop sizes to $\frac{1}{16}$; it is also divided into 10 parts and into 12 parts when such divisions serve any good end. All such divisions have their uses and lead to no confusion. The inch squared is the base of our strains and pressures. The inch cubed gives us capacities. Later, I will speak of 12 and 36 inches squared and cubed. This one unit, the inch and pound weight of 7000 grains Troy, is all that a machinist needs to carry on his business. His inch is the same inch as is used in England and in the Russian machine shops. His pound is the pound in common use in England.

In America we have dropped some needless weights and measures, just as we have seen fit to drop the letter u from some of our words. We do not use in the machine shop the ton of 2240 pounds nor its quarter or its hundred weight; we do use a weight called "ton of 2000 pounds." This is the factor weight in strains, and by it we sell machinery. Other trades may retain some of these useless things; I am speaking only of machine shop practice.

The unit of measurement in France and in Germany is the *millimetre*. It is not and cannot be the metre for the following reason: The great majority of all sizes used in the construction of any machine, whether it be big or little, are less than one metre. By the use of the millimetre only, decimals are avoided. 8 millimetres must be written 8 in the millimetre scale, while it must be written ·008 in the metric scale. This is reason enough, for by the use of millimetres only, confusion of signs is avoided, and the *danger incident to decimals* is also avoided, hence *all* drawings are figured in millimetres only, up to dimensions measuring many thousand millimetres. This little dimension is then squared and cubed, or ten or a hundred millimetres are squared and cubed, for the uses corresponding to our squared and cubed inch and foot. As may be expected, happy coincidences of conveniences are found in either system. Thus an ardent metric advocate instances that 1 kilo to the square centimetre is just one atmosphere. We say 15 pounds to the inch is an atmosphere. Neither one is right, but the 15 pounds to the inch is 1 per cent. nearer right than the other is.

For a machinist who seldom uses atmospheres a happy coincidence on the other side will be of more service. It so happens that wrought iron bars with parallel sides measure in square inches of this section just one-tenth of their weight in pounds per yard. Now, inasmuch as "shapes" in iron are rated by the pounds per yard, for convenience in large structures, so it comes to pass that, when we know the weight per yard of any wrought iron "shape," we know at once its sectional area. In as much as compression and extension and factors of safety are involved in a knowledge of cross section it is handy to be able to find it so readily, is it not? A shape iron, 80 pounds to the yard, has 8 square inches area of section. If it is good for 10,000 per square inch in extension we may load it with 80,000 pounds.

I have set out to compare the two scales—to compare the two units, rather, after an experience of twenty years with both. The inch is 25·4 times larger than the millimetre. These are the two dimensions we are to compare.

We will begin in the drawing room. Here "the inflexible laws of mechanics" find their first expression in form on paper. Few machines, or even parts of machines, can be drawn full size. Hence comes the need of "scales." There is reason in all things, even in scales. The unwritten law of most machine shops is to make every drawing as large as possible, as near full size as the nature of the subject and the dimensions of the paper used will permit. We have in our drawing room about 125 drawers, each of which will take in, without folding, drawings 52 inches (1320 mm.) long by 33 inches (840 mm.) wide. This is about as large a sheet as we can use to advantage, and tracings from these are not unmanageable in the work shop.

For metrical drawings we can use the following scales *only:*

Full size in which	1 mm. = 1 mm.
One-half size in which	½ mm. = 1 mm.
One-fifth " "	2 mm. = 1 cm. or 2 cm. = 1 dm.
One-tenth " "	1 mm. = 1 cm. or 1 cm. = 1 dm.
One-twentieth size in which	5 mm. = 1 dm.
One-twenty-fifth size in which	4 mm. = 1 dm.
One-fiftieth " "	2 mm. = 1 dm.

Down to the one-tenth scale the dimensions can be read from a good millimetre rule, for the one-twentieth, the one-twenty-fifth and the one-fiftieth scales must be constructed. The jump from one-half to one-fifth size is unfortunate. Could we conveniently quarter the

whole size we would have an increased area section, a matter of much moment. The $\frac{1}{5}$ of 10 inches is 2 inches, and the square of 2 is 4. The $\frac{1}{4}$ of 10 inches is $2\frac{1}{2}$ and its square is $6\frac{1}{4}$, a gain in size of over 50 per cent; a gain in comfort, in convenience and in eyesight. Here we catch the first glimpse of the advantage of our own system; for with it draughtsman can, from an ordinary well-divided inch rule, obtain the following scales: Full $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{6}$, $\frac{1}{8}$, $\frac{1}{12}$, $\frac{1}{16}$, $\frac{1}{24}$, $\frac{1}{32}$, $\frac{1}{48}$, $\frac{1}{64}$—12 gradations, as compared to 7, and to these 12 can be added with perfect ease 5 of the others, making 17 in all, if the preference be for the decimally divided inch, a scale carried in the tool box of every machinist, and obtainable from the two-foot rule in so common use.

The scale series in most common use is that of $\frac{1}{2}$, $\frac{1}{4}$ and $\frac{1}{8}$; this halves down from whole size and can be raised, in rapid drawing, by taking off diameter sizes from one drawing and using them as radius dimensions in the other, a process impossible between $\frac{1}{2}$ and $\frac{1}{5}$ sizes.

The true value of this extended series of scales, with its peculiar advantages, is manifest to any one familiar with both, *and admits of no dispute.* Is it a wonder that draughtsmen brought up under a metric rule take so kindly as they do to our unphilosophical system?

Drawing is but a small part of the engineer's work. More or less calculating has to be done; many hours must be spent in figuring strains, estimating weights, determining speeds and what not. This brings us to the test of convenience in calculation, to the stronghold of the metric advocates. It is just here that Dr. Edward Wigglesworth in his metric tracts comes out the strongest in his peculiar style. He says that Americans, self-ruling, are really too lazy, while merely claiming to be too stupid, to use the system. He says, "Shame on a country which to party gives up what was meant for mankind." It is claimed that the decimal notation of the metric rule gives great facility in calculating, but that this is not its sole advantage.

Mr. Frazer says: "Let the carpenter or mason be asked how many tons of water a structure, whose *external* (I guess he means *internal*) dimensions are given, by his rule, will contain, and they will acknowledge that the decimal division is not the only advantage of the metric system, but that another is the perfect relation of extension, capacity and weight." For a structure 5 feet square and 10 feet deep the carpenter would divide, in his head, 250 by 32 and say 8 tons, nearly, or 7·8125 tons exact of the tons of 2000 pounds in use, in all such measurements. The metric system would give for a nearly similar

structure, say $1{\cdot}5 \times 1{\cdot}5 \times 3$ metres, a result obtained by multiplying only; but what then? This problem applies to water only. If these spaces were to be loaded with bricks the metric multiplication must be still further multiplied by the specific gravity of bricks, thus: $1{\cdot}5 \times 1{\cdot}5 \times 3 \times 1870 = 12{,}622{\cdot}5$ kilos, while our mason's sum would read $5 \times 5 \times 10 \times 125 = 31{,}250$ pounds of common hard bricks, with an ease of calculation rather in favor of the two-foot rule.

I have mentioned the inumerable books which have been prepared, simplifying processes of calculations by tabulating the results of experiments on a basis of the inch unit. Of these books the English experiments form a large bulk of the valuable engineering knowledge of the world. Hodgkinson, for example, experimented with the crushing resistances of various substances, and the result of his experiments are in the possession of all engineers. He took samples in cylindrical form, 1 inch diameter, 2 inches long each, for these experiments. Armengaud quotes these experiments and tabulates the results, saying they were obtained by Hodgkinson, *avec des cylindres de* $0{\cdot}^{m}0254$ *de d*^{tre} *sur* $0{\cdot}508$ m. *de haut*^{r} $'' = 1'' \times 2''$, and from these he deduces, for example, that *ash* has a crushing resistance of from 610 to 653 kilos per square centimetre.

Mr. Trautwine, quoting Eaton Hodgkinson's experiments, also tells us that ash, weighing from 45 to 53 pounds per cubic foot, has a crushing value of 8600 pounds per square inch. Now, 1 pound per square inch = ·0703077 kilo per square cm., or 1 kilo per square cm. = 14·2232 pounds per square inch, $\frac{8600 \text{ pounds}}{14{\cdot}22}$ = about 605 kilos to the square cm. Here, from Trautwine's deduction, the metric using engineer will employ 605 as a factor where we use 8600 in the same case. He, because his unit of measurement is less, or, rather requires more figures to express it, multiplies these many figures by a lesser factor, while we, expressing our dimensions with lesser figures, use with these figures a larger factor. In other words, we can complete our calculation sooner because we are able to deal with the largest measures compatible with convenience. We can use the cubic inch, the cubic foot or the cubic yard, at our pleasure, just as the mechanic selects his tools in accordance with the extent of his work, and don't [illegible] time [illegible] driving at a rail-road spike with a tack hammer.

I have before me, as I write, French books and German books on

mechanical engineering. In some, both French and German, all or nearly all, formulas for strains are expressed in kilos per square cm., while Prof. Reuleaux, in his many valuable books of reference, seems to adhere to kilos per square millimetre. Now, to test the matter of convenience, in a way familiar to all mechanical engineers, let us go to Reuleaux for our information as to the strength of cast iron, in the familiar equation for beams of $W = \frac{4\,s\,b\,h^2}{6\,l}$. Reuleaux says the value of s may be taken as 4 kilos per square mm.; this equals 400 kilos per square cm., or 5689 pounds per square inch. Let our example be a cast iron beam of rectangular section, 9 inches deep, 4 inches wide, and 10 feet between its supports; ~~given~~, to find its safe load in the middle. Let us round up these dimensions into a somewhat similar beam, measured in mm., 230 × 100 × 3000. Now, $h = 230$ or 9, $b = 100$ or 4, $L = 3000$ or 120.

The formula then reads

$$\frac{4\times 4^{k}\times 100\times 230\times 230}{6\times 3000} = 4702^{k} \text{ for all dimensions, in mm.}$$

or

$$\frac{4\times 400^{k}\times 10\times 23\times 23}{6\times 300} \text{ for all dimensions, in cm.}$$

If we take 6 from the denominator, then

$$\frac{4\times 66{\cdot}6\times 10\times 23\times 23}{300}$$

If we make the formula good for cast iron only, and use centimetres in the numerator and metres in the denominator, which is the best we can do, $\frac{2{\cdot}664\,b\,h^2}{l}$ for cast iron $= \frac{2{\cdot}664\times 10\times 23\times 23}{3}$.

Compare this with $\frac{4\times 5689\times b\,h^2}{6\,l}$ which reduces to $\frac{316\,b\,h^2}{l}$ for cast iron, and reads $\frac{316\times 4\times 9\times 9}{10}$.

My note-books are full of such examples as this; it has been my wish to test this matter thoroughly; my experience covers many examples of engineers and draughtsmen educated in metric-using countries, who, when they come to us learn to use our measures as quickly as we can learn to use theirs, but adopt our methods of calculation as involving fewer figures. Thus, for all practical purposes, in strains, what

will be strong enough in kilos, if we assume two pounds to the kilo, will be near enough right, and if the "grand truth of mechanics is that properties or dimensions of parts of machinery to accomplish any given purpose will be unaffected by any standard of length or weight applied to the part," it is therefore possible to arrive at the theoretical proportion by either system, and it is presumable that the workman will select the easiest one to work with, the more so if the easiest one happens to be the one he has been most used to. I have yet to see the example of a metric-educated draughtsman working in millimetre calculations on an inch-measured machine, while with our own experience with both we could follow him in either.

Cubic inches go farther than cubic millimetres, *i. e.*, they involve fewer figures in their expression; because a cubic inch is 16000 larger than a cubic millimetre, it is 16 times larger than a cubic cm.; and while, again, the litre is may be 64 times larger than the cubic inch, yet is the cubic foot 27 times larger than the litre, and between the litre and the cubic metre there is no unit of measurement; 10 litres, like our gallon, has an edge only expressable in decimals.

The harmonious relation of extension, bulk, weight and all that comes out strongest when we deal with distilled water. Away from that precious fluid, and we are required to know and use the weights of matter as they relate to water. I must confess I see no difference in favor of hunting up in books the specific gravity of matter, or in looking for the weight of matter in pounds per cubic inch, or foot, or yard.

With distilled water engineers have little to do; when they note the solid matter accumulating in their boilers, they wish they had more to do with it. In hydraulic calculations the weight of distilled water, however, may be near enough to the weight of the water they have to deal with to enable them to reap all the advantages desirable from the system, did not the small units, the millimetres, or the many figures in the decimals of the metre, mar the result in a labor-saving point of view.

The value of the drawing room system is tested or tried when the drawings reach the machine shop. It is there that errors are found out. An incorrectly figured drawing costs nothing on account of the errors so long as that drawing rests quietly in its drawer; but it costs fearfully when the error is discovered in the partially finished machine. All engineers agree on one thing, viz., the fewest possible figures that

can be used to express dimensions clearly, the easier it is to work to the drawing, and the less liability to make mistakes. Beautiful as is a decimal system in calculation, and we all use it, save in mental arithmetic, it has been found advisable to avoid the use of decimals as far as possible on the drawings used in our workshops, even in metric using countries. A misplaced point is an easy error to make, and may cause no end of trouble and expense.

I had hoped for gain in the drawing room from the use of metric scales; I expected to find more than in the machine shop; I have been disappointed in both.

In the machine shop we come to test the value of shop sizes and merchant sizes, or rather the series possible in both, with one or the other system. For what is in use abroad, we look to Germany rather than to France for information useful to us, inasmuch as in Germany the metric system was taken up at a late day, and was introduced in its entirety without shock. To united Germany anything was better than their frightful confusion of 15 inches in use, all differing from the inch still used with their screw threads, and differing from the inch of England. The metric system is incomparably better than their before entire want of any uniformity. With us the matter is very different, as will be seen more clearly as we advance. We divide our unit, in practice, into just what parts are best suited to express our practical wants, and the system in our machine shops is uniform over a continent.

The first item of manufactured matter entering the machine shop door is bar iron. The merchant sizes of round, square, etc., in America, are by $\frac{1}{16}$, by $\frac{1}{8}$, by $\frac{1}{4}$, etc. In Germany, similar bars advance in size by 1 mm. up to 40, by 2 mm. from 40 up to 80, and by 5 mm. above 80. This system is memorizable by 40 and 80—by 1, 2 and 5. It is the best that can be done with a system tied up to an unhalvable scale. It does not agree with the English or American merchant sizes except in a few sizes. The system of bolts, diameters and threads per inch common or general over the continent of Europe is that known as the Whitworth system. They still adhere to this system as they do to the English system of gas and steam pipes and their fittings. The Whitworth system pitches its threads to even numbers or half numbers per inch in length. These pitches are easily obtained from the lead screws of all lathes, which are 2, 4 or 6 threads per inch as a rule. Having given up the inch, the Germans formulate their threads

per diameter (see tables at the end of this paper). For the names of the bolts, they must either retain their English names, and call a 25·4 mm. bolt one inch, or they must call it what it is, 25·4 mm., but some call it 25 mm., and make it ·4 mm. larger. This inch bolt has 8 threads per inch, and, as the diameter, too, is 1 inch, it can be said to have 8 threads per diameter. A $1\frac{1}{8}$-inch bolt measures 28·6 mm.; it may be called 29 mm. size; it must be cut out of 29 mm. iron, the nearest merchant size, with a loss of $\frac{4}{10}$ of a millimetre. This loss don't seem much, but the dies which have to cut it off tell the story very soon. The Whitworth scale gives the same pitch to $1\frac{1}{8}$ and $1\frac{1}{4}$ screws, viz., 7 per inch. The exclusive metric shops call the one $7\frac{7}{8}$ threads per diameter, and the other $8\frac{3}{4}$, and yet they are practically the same and must be cut with the same combination of change wheels on the lathe. Here is a precious example of what comes from trying to harmonize two systems under one nomenclature. The screw system in general use is so good, it has been so long in use, its disturbance would shock so many interests, that it is unwise to give it up, as unwise as it would be to adopt the American gas pipe system in place of the English, or for us, for sake of uniformity with England and Germany, we should attempt to force the adoption of their system into our houses.

Imagine the hue and cry if some "benevolent despot," for the good of mankind in general and Europeans in particular, should direct us to change our "fittings" to English standards, none of which would fit the pipes we have in our houses. Why, we are even vexed enough if we are sold a "sleeve" which will not fit a pipe put in place thirty years ago.

America has, for the last half century, been striving in its own way, towards equalization of its standard sizes. The immense railroad industries demand this. Standard wheels on standard axles—standard fit sizes for both—are all founded on an inch scale of sizes.

Standard shafting for mill gearing gives a good example. It has been demonstrated that bars carefully rolled to size in rounds can be reduced to turned shafting with the loss of $1\frac{1}{2}$ mm., or $\frac{1}{16}$ inch to the diameter. Hence, bars 2, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3 inches, etc., are made into shafts $\frac{1}{16}$ less in diameter, sold by their full size names, *i. e.*, by the name of the iron from which they have been made and designated by the affix "shafting size." A 2-inch shafting size bar measures $1\frac{15}{16}$ inch, and a pulley ordered to-day with an eye to fit a $2\frac{1}{2}$ or a 4-inch shaft made

thirty years ago will be found to be to size. Now this American shafting sells freely in Europe and no one complains of its size. He can command the markets of the world who can make the best machinery at the least cost, and that machinery will be taken and used and no questions asked about its inches or its millimetres.

A scale of shafting sizes so uniform and so easily expressed by $\frac{1}{4}$ up to $3\frac{1}{2}$ and by $\frac{1}{2}$ inches to sizes above 3, is met in metric countries by the ease of an advance by 5 mm. only. To obtain the economy of American shops their shafting sizes should be $1\frac{1}{2}$ mm. less than their name, *i. e.*, a 100 mm. shaft should be made $98\frac{1}{2}$ mm. diameter, but the Germans have seen fit to retain even sizes and thus are obliged to use 57 mm. iron to make a 55 mm. shaft, and 93 mm. iron to make a 90 mm. shaft, while on still larger shafts they must be content to lose 5 mm. at each turning. Such is the usage now, so far as we can learn.

The shop sizes in America harmonize with the merchant sizes and with convenience. We cannot change them. It would be unwise, I think, to do so in face of the obtainable metric sizes if we could. One other example of good and bad systems, and I have done with this part of our subject.

An essential of all machine shops is a drill system; a series advancing by $\frac{1}{16}$ up to 1 inch, and by $\frac{1}{8}$ inch up to 2 inches, is equivalent to an advance by $1\frac{1}{2}$ mm. in a metric series. Such an advance as $1\frac{1}{2}$ mm. is impracticable, because it must be memorized entire; it affords no holding place for the memory. Twist drills were first made in America; they were so good, so useful, that American drills came to be the rage in Europe. After a time good makers there began their manufacture. I will mention one house, founded in 1834, that of Heilmann, Ducommunn & Steinlen, at Mulhouse (Alsace), one of the best known houses in all Europe. They make twist drills from 10 mm. up to 50 mm., advancing by 1 mm., but their price list tells us that the sizes marked in bold face type are the sizes in use in their own shop. These sizes are: 10, 12, 15, 18, 20, 23, 25, 28, 30, 32, 35, 37, 40, 42, 45, 47, 50. Here a series of sizes approximating the English ones is adopted, but it is a series which must be memorized entire, as its advance is not by two or by three either, in regular sequence. We cannot question the wisdom of the men who have selected these shop sizes to meet their known wants; they rank too high as workmen, they know too much to challenge criticism. Doubtless, this scale of

sizes is about the best they can do with the metric system; we would not tie ourselves to it. I could continue the list of practical difficulties until I had filled a volume. They run through the entire list of all that goes to make up the requirements of our profession, and show how unwise we would be to change, if we could do so for the sake of harmony with Europe. We have not adopted the Whitworth system of screws in America, and yet, by so doing, we would place ourselves in harmony with all Europe. We recognize objections to the system, and when those objections were clearly pointed out by Mr. William Sellers and he proposed a system free from the objections, his system was accepted by the committee of the Franklin Institute and then by many departments of our government. Had the metric system shown itself to be the perfect system it is claimed to be, it too, would have been taken up more generally at a time when it was easier to have done so than now.

The American mind is quick to note what is to the advantage of American mechanics. We take up quickly what is good to hold to, and we will not accept what we have demonstrated to be less useful. This was made manifest to Prof. Reuleaux, Director of the Industrial Academy, Berlin, and is expressed by him in his report on motors and machines at Paris Exposition, 1867. In commenting on the many novelties from America he says, "Upon the whole it may be said that in machine industry England has partly lost her formerly undisputed leadership, or that she is about to lose it. The healthy young transatlantic industry, which continually withdraws from us energetic and intelligent heads and robust hands, makes, with the aid of her peculiar genius, the most sweeping progress, so that we shall soon have to turn our front from England westward." Then, in commenting on the rapidity with which American ideas were finding a home in Germany, speaks of the genius for inventions of this kind as peculiar to us—"They are distinguished from us by more direct and rapid conception. The American aims straightway for the needed construction, using means that appear to him the simplest and most effective, whether new or old." * * * "The American really constructs in accordance with the severest theoretical abstractions, observing on the one side a distinctly marked out aim, weighing on the other the available means or creating new ones, and then proceeding regardless of precedents, as straight as possible for the object." * * * "This spirit is strikingly

prominent in the (Wm. Sellers') system of screw threads which he has boldly placed alongside of the old venerated Whitworth system, in spite of the terror of its numerous adherents, after he had discovered actual deficiencies. A proper valuation of this proceeding contains the most instructive hints for our higher technical institutions."

There is an irreconcilable discord between the inch and the divisions of the metre. The inch has become fixed to a greater extent in dollars and cents, in fitness and convenience, in this country than in Germany, and yet there, in some cases I have shown, it cannot be given up. To keep our scale of sizes and use French dimension sizes would "furnish a precious example of the simplicity of the decimal system." I was a signer of the majority report of the Franklin Institute which opposed the compulsory adoption of the metric system. That report was prepared and written by the chairman, Mr. Wm. P. Tatham, since made President of the body which adopted it, as their view of the matter. Mr. Tatham is a man of culture and a hard student. His business as maker of lead pipes would have been less affected than that of almost any other manufacturer by the introduction of the metric system. He said, and I subscribed to the statement, that he believed that the ultimate benefits of the change proposed would be of less value than the damages during the transition. This was on the suppositious view that ultimately some would be benefitted. As an engineer I can see no possible good to come to American machinists from the change. Its introduction exclusively would not diminish his labor in any way; it would not cheapen his product, it would increase its cost. It is in fact, however, so impossible in view of existing matters and existing harmony in interchangeable matter, that should the metric standard be made the only legal standard in America to be used in buying and selling, the engineering establishments now in existence could not heed the law, but must perforce use their existing tools and gauges of precision, and continue to make material in conformity with existing matter.

The metric system was admitted here to an equal fostering in point of law in 1866. It had not been legalized in any way when we, for good reasons, introduced it into our own workshop in Philadelphia, and yet, at that time, we asked no one's permission to do what we pleased in the metrological management of our own business. We had a chance to try the system in making something which did not clash

with existing merchant sizes; once having perfected an organization in this department we became fixed in its continuance. Precisely the same reasons why we cannot change our general system into the metric hold against our giving up the metric system in the departments where it is in use.

If the change to the metric system will aid commerce, let the merchants do as we have done—try it. Commerce depends, in a large measure, on the possible out-put of our workshops. The engineer controlling the workshop and who, to be successful, must be a merchant too, knows too well how he stands to give up a practically useful system more convenient to him after having tried both, for the sake of any fancied conformity with other countries. He can give up no vantage ground. His success in his life-battle in these days of active competition depends upon wise economies to enable him to prosper. He has no more reason to cripple himself with an inconvenient system of metrology than he has to give up a tariff of protection on his production in order to make it easier for the world to compete with him.

I am tempted to touch on the educational view of the subject, but will content myself with very few words. When engineers are told that the change to the metric system would save two years, or one year, in the school life of every child, they ask how many years are now devoted to mathematics only, in the average four years' schooling of the mass of our boys, and ask, what is to be lopped off to make this saving? Many a good workmen who has risen to a high rank among educated mechanical engineers had too few years at school to admit of a month's saving in any one branch of his studies.

It is the thing just now to favor the change. A young engineer enlisting himself in the ranks of the metrical reformers (?) buys a cheap scientific notoriety. He is brought into sympathy with the self-constituted advanced thinkers. Those who oppose the change, after having become familiar with both, are said to "sever themselves from the congenial sympathy of the enlightened public opinion of to-day." The mechanical engineer can accept nothing as true until he has demonstrated the truth by experiment; at least, in anything capable of being put to the test of experiment. It is in the power of any intelligent man to test the metric system as others have done. He will, I think, find that the *savants* who originated the scheme before me-

chanical engineering, as it now exists, was known as a profession, made the mistake of beginning at the wrong end, the big end of the scale, the size of the world, and by the time they had cut it up or down to human wants it came out less fitted to human requirements than if they had recognized in the beginning the needs of the beings who were to use it.

Our metrological reformers urge us to adopt a new system in place of our present one, a system that harmonizes in no way with anything we now use. This new system is practically based on a certain measure over 39 inches long. This is cut up into 1000 parts, and 100 of these parts cubed gives their primary vessel of measurement. The contents of this vessel in distilled water under certain conditions is their pound weight. Had the English yard of 36 inches been so treated it would have been as good a system, but no better. It would have been as inapplicable comfortably to our profession as is the metric The wonderful extension of the metric system to time and infinite space was given up as impracticable long ago, and we are now asked to bear the shock of a mighty change to use this *inconvenient* system, this unhandy system of ten, for the sake of uniformity with some other peoples' of the world.

In conclusion, when we take into consideration the enormous interests involved in manufacturing in America; if it is, as we think, unwise to tamper with the existing metrology of our workshops, the question may well be raised as to the wisdom of enforcing the metric system in trade generally. The practical mind of Americans has already dispensed with much useless stuff, coming to us with our old metrology; is it not better to continue to amend what we have, to encourage the uniformity so desirable, rather than to attempt to make all things new; but in no respect practically better, at so frightful a cost ?

WHITWORTH'S SCREWS.

In use in Europe, especially in Germany.

Diameter.—English Inch.	Diameter.—Prussian Inch.	Diameter.—Millimetre.	Diameter at root of thread.—English Inch.	No. of threads per Diameter.	No. of threads per Inch—English.	Diameter.—English inch.	Diameter.—Prussian inch.	Diameter.—Millimetres.	Diameter at root of thread.—English Inch.	No. of threads per Diameter.	No. of threads per Inch—English.
$\frac{1}{4}$	0·243	6·4	0·186	5	20	$2\frac{1}{4}$	2·185	57·1	1·930	9	4
$\frac{5}{16}$	0·303	7·9	0·241	$5\frac{5}{8}$	18	$2\frac{1}{2}$	2·428	63·5	2·180	10	4
$\frac{3}{8}$	0·364	9·5	0·295	6	16	$2\frac{3}{4}$	2·671	69·8	2·384	$9\frac{5}{8}$	$3\frac{1}{2}$
$\frac{7}{16}$	0·425	11·1	0·346	$6\frac{1}{8}$	14	3	2·913	76·2	2·634	$10\frac{1}{2}$	$3\frac{1}{2}$
$\frac{1}{2}$	0·486	12·7	0·393	6	12	$3\frac{1}{4}$	3·156	82·5	2·857	$10\frac{9}{16}$	$3\frac{1}{4}$
$\frac{5}{8}$	0·607	15·9	0·509	$6\frac{7}{8}$	11	$3\frac{1}{2}$	3·399	88·9	3·107	$11\frac{3}{8}$	$3\frac{1}{4}$
$\frac{3}{4}$	0·728	19·0	0·622	$7\frac{1}{2}$	10	$3\frac{3}{4}$	3·642	95·2	3·323	$11\frac{1}{4}$	3
$\frac{7}{8}$	0·850	22·2	0·733	$7\frac{7}{8}$	9	4	3·885	101·6	3·573	12	3
1	0·971	25·4	0·840	8	8	$4\frac{1}{4}$	4·127	107·9	3·805	$12\frac{7}{32}$	$2\frac{7}{8}$
$1\frac{1}{8}$	1·092	28·6	0·942	$7\frac{7}{8}$	7	$4\frac{1}{2}$	4·370	114·3	4·055	$12\frac{15}{16}$	$2\frac{7}{8}$
$1\frac{1}{4}$	1·214	31·7	1·067	$8\frac{3}{4}$	7	$4\frac{3}{4}$	4·613	120·6	4·285	$13\frac{1}{16}$	$2\frac{3}{4}$
$1\frac{3}{8}$	1·335	34·9	1·162	$8\frac{1}{4}$	6	5	4·856	127·0	4·535	$13\frac{3}{4}$	$2\frac{3}{4}$
$1\frac{1}{2}$	1·457	38·1	1·287	9	6	$5\frac{1}{4}$	5·098	133·3	4·790	$13\frac{25}{32}$	$2\frac{5}{8}$
$1\frac{5}{8}$	1·578	41·3	1·369	$8\frac{1}{8}$	5	$5\frac{1}{2}$	5·341	139·7	5·020	$14\frac{7}{16}$	$2\frac{5}{8}$
$1\frac{3}{4}$	1·700	44·4	1·494	$8\frac{3}{4}$	5	$5\frac{3}{4}$	5·584	146·0	5·238	$14\frac{3}{8}$	$2\frac{1}{2}$
$1\frac{7}{8}$	1·821	47·6	1·591	$8\frac{7}{16}$	$4\frac{1}{2}$	6	5·827	152·4	5·488	15	$2\frac{1}{2}$
2	1·942	50·8	1·716	9	$4\frac{1}{2}$						

TABLE OF SCREWS.—By Reuleaux.

Diameter of Screw. d = mm.	Diameter at root of Thread. d = mm.	Threads per 10 mm.	Thickness of Head. Millimetres.	WHITWORTH'S.		
				Diam. of Screws. d = Eng. in.	Threads per 1 in. Engl.	Threads per length = diam.
6	4·1	7	7	$\frac{1}{4}$	20	5
8	5·9	6	8	$\frac{5}{16}$	18	$5\frac{5}{8}$
10	7·7	$5\frac{1}{2}$	10	$\frac{3}{8}$	16	6
12	9·5	5	11	$\frac{1}{2}$	12	6
15	12·2	$4\frac{1}{2}$	13	$\frac{5}{8}$	11	$6\frac{7}{8}$
18	14·9	4	15	$\frac{3}{4}$	10	$7\frac{1}{2}$
21	17·6	$3\frac{3}{4}$	17	$\frac{7}{8}$	9	$7\frac{7}{8}$
24	20·3	3	20	1	8	8
27	23·0	3	22	$1\frac{1}{8}$	7	$7\frac{7}{8}$
30	25·7	$2\frac{1}{2}$	24	$1\frac{1}{4}$	7	$8\frac{3}{4}$
34	29·3	$2\frac{1}{2}$	27	$1\frac{3}{8}$	6	$8\frac{1}{4}$
38	32·9	$2\frac{1}{2}$	29	$1\frac{1}{2}$	6	9
42	36·5	$2\frac{1}{8}$	32	$1\frac{5}{8}$	5	$8\frac{1}{8}$
46	40·1	$2\frac{1}{8}$	35	$1\frac{3}{4}$	5	$8\frac{3}{4}$
50	43·1	$1\frac{7}{8}$	38	$1\frac{7}{8}$	$4\frac{1}{2}$	$8\frac{7}{16}$
55	48·2	$1\frac{7}{8}$	41	2	$4\frac{1}{2}$	9
60	52·7	$1\frac{5}{8}$	45	$2\frac{1}{4}$	4	9
65	57·2	$1\frac{5}{8}$	48	$2\frac{1}{2}$	4	10
70	61·7	$1\frac{3}{8}$	52	$2\frac{3}{4}$	$3\frac{1}{2}$	$9\frac{5}{8}$
75	66·2	$1\frac{3}{8}$	55	3	$3\frac{1}{2}$	$10\frac{1}{2}$

TABLE OF AMERICAN AND ENGLISH GAS PIPES.

Nominal Diameter.	Act'l outs. Diam. in Engl. in.	No. of Threads per inch.	Act'l outs. Diam. in Engl. in.	Act'l outs. Diam. in mm.	No. of Threads per inch.	Nominal Diameter.	Act'l outs. Diam. in Engl. in.	No. of Threads per inch.	Act'l outs. Diam. in Engl. in.	Act'l outs. Diam. in mm.	No. of Threads per inch.
	U. S. Standard.		English Standard.				U. S. Standard.		English Standard.		
⅛	0·405	27	0·406	10·318	19	2¼	.....	.....	2·625	66·674	11
¼	0·54	18	0·531	13·493	19	2½	2·875	8	3·0	76·199	11
⅜	0·675	18	0·625	15·875	19	2¾	.....	.....	3·125	79·374	11
½	0·84	14	0·812	20·637	14	3	3·5	8	3·5	88·898	11
⅝	.....	.....	0·906	23·018	14	3½	4·0	8	3·937	100·01	11
¾	1·05	14	1·031	26·194	14	4	4·5	8	4·437	112·71	11
⅞	.....	.....	1·187	30·162	11	4½	5·0	8	.....	.....	.....
1	1·315	11½	1·312	33·337	11	5	5·563	8	.....	.....	.....
1¼	1·66	11½	1·625	41·274	11	6	6·625	8	.....	.....	.....
1½	1·9	11½	1·875	47·624	11	7	7·625	8	.....	.....	.....
1¾	.....	.....	2·125	53·974	11	8	8·625	8	.....	.....	.....
2	2·375	11½	2·375	60·325	11	9	9·688	8	.....	.....	.....
						10	10·75	8	.....	.....	.....

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